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BY

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METHODS AND COSTS OF MINING AT HARTLEY-GRANTHAM MINE, TRI-STATE ZINC AND LEAD DISTRICT[1]

By Oliver W. Keener[2]

INTRODUCTION

This paper describing the methods and costs of mining at the Hartley-Grantham mine of the Century Zinc Co. in the Tri-State Lead and Zinc district is one of a series being prepared by the United States Bureau of Mines on mining practices, methods, and costs in the various mining districts of the United States.

LOCATION, HISTORY, AND GEOLOGY

The Hartley-Grantham Mine is located just outside the city limits of Baxter Springs, Kans., as shown in Figure 1. A plan of the mine is given in Figure 2, and Figure is a cross section through A - A of Figure 2.

The lease to the mine, which is located on a 40-acre tract, was acquired in September, 1925, and exploration by churn drilling was begun soon afterwards. The shafts were sunk and development was started in 1927. Upon completion of the mill in 1928 production was begun.

The surface formations consist of shales and sandstones of the Pennsylvania age (fig. 4). The cherokee shale underlies the soil, clay, and sandstones at a depth of 12 to 35 feet and varies in thickness from 15 to 50 feet. Immediately below this, with a marked unconformity, lie the limes and flints of the Boone formation of Mississippian age. At an average depth of 140 feet is a thin bed of Short Creek oolite varying in thickness from 5 to 10 feet. Figure 5 shows a section across the ore body taken at right angles to the strike.

ORE DEPOSITS

The ore minerals occur as sphalerite and galena in a brecciated, loose, bowldery formation of flint associated with jasperoid, calcite, and some lime, in a channel or trough of brown lime. This channel apparently bears a distinct relationship to the valleys found in the Cherokee shale lying directly underneath. On the other hand, the ore in some mines in the Tri-State district occurs along the edges of the shale troughs and is not found beneath the lowest contour.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment be used: "Reprinted from U. S. Bureau of Mines Information Circular 6286."

[2] One of the consulting engineers, U. S. Bureau of Mines. Mining Engineer, Century Zinc Co.

Beneath this shale channel, or more strictly in the channel formed by the brown lime, is the only large body of ore found. There is, however, some evidence of a sheet ground horizon at around 240 feet.

The ore body extends entirely across the lease with a strike approximately N. 30° W. and a dip slightly to the southeast. The average width is 120 feet and the height is 60 feet. The main working level is at 200 feet. In the south portion of the mine a minor horizon is being worked at the 125-foot level. This averages 35 feet in height.

The bowldery condition of the walls and roof requires constant inspection and trimming, but by keeping the roof well arched, falls of rock are rare. When falls do occur it is usually during blasting when no one is in the mine.

PROSPECTING AND EXPLORATION

Prospecting was done entirely by churn drilling, and 43 holes were drilled by the present company. No geophysical methods were employed. The first holes were drilled ahead of a proved ore body on the adjoining lease to the north and were concentrated along the estimated probable trend. Later some cross sections were drilled at right angles to the strike and some general drilling was done, but outside the channel of the main ore body these holes proved to be barren or of no commercial value.

The extent and grade of the ore body was well defined by this method of prospecting and consequently no sampling or long hole drilling (as in some mines operated by the company) was necessary. At present, however, a winze is being sunk to prospect the sheet ground.

The tonnage estimates are prepared prior to development by a careful analysis of the assays of the cuttings. The same method employed at the Barr mine[3] is used.

METHODS OF DEVELOPMENT AND MINING

The method of development and mining at this mine is typical of the practice of the Tri-State district. The ore is loaded into "cans" 32 inches in diameter by 30 inches high holding approximately 1,200 pounds of ore. The cans are trammed by hand to the "hookers" platform, where they are hoisted to the top of the derrick, dumped into the hopper by a swinging dump, and returned to the bottom without being unhooked.

Tramming was originally done by mules but the acid water was so harmful to their feet that the mules were removed from the mine. A small storage-battery type of trammer is being purchased.

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[3] Keener, Oliver W., Methods and Cost of Mining at Barr Mine, Tri-State Zinc and Lead District, Information Circular 6159, Bureau of Mines, 1929, 9 pp.

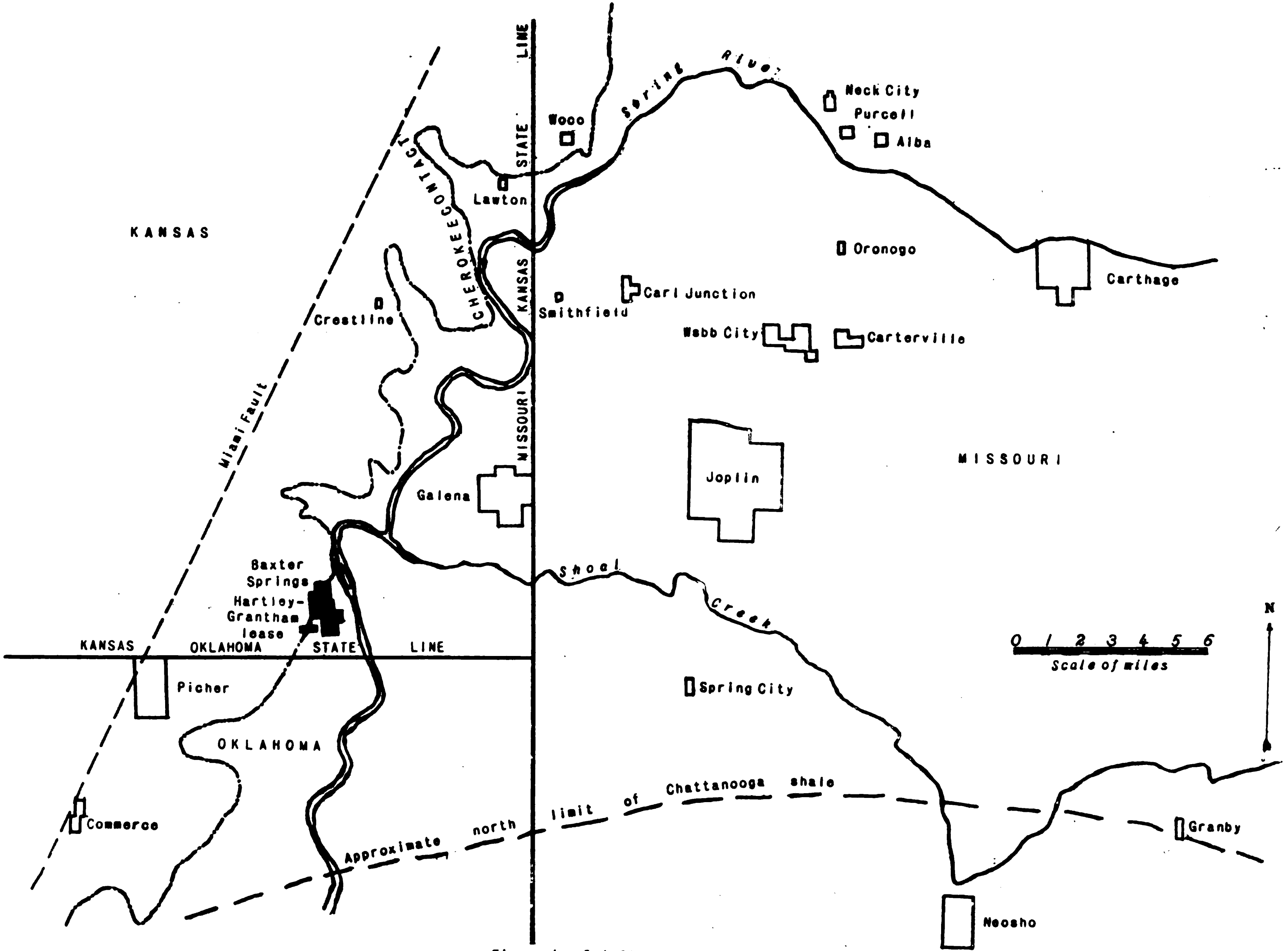


Figure 1.- Tri-State lead and zinc district

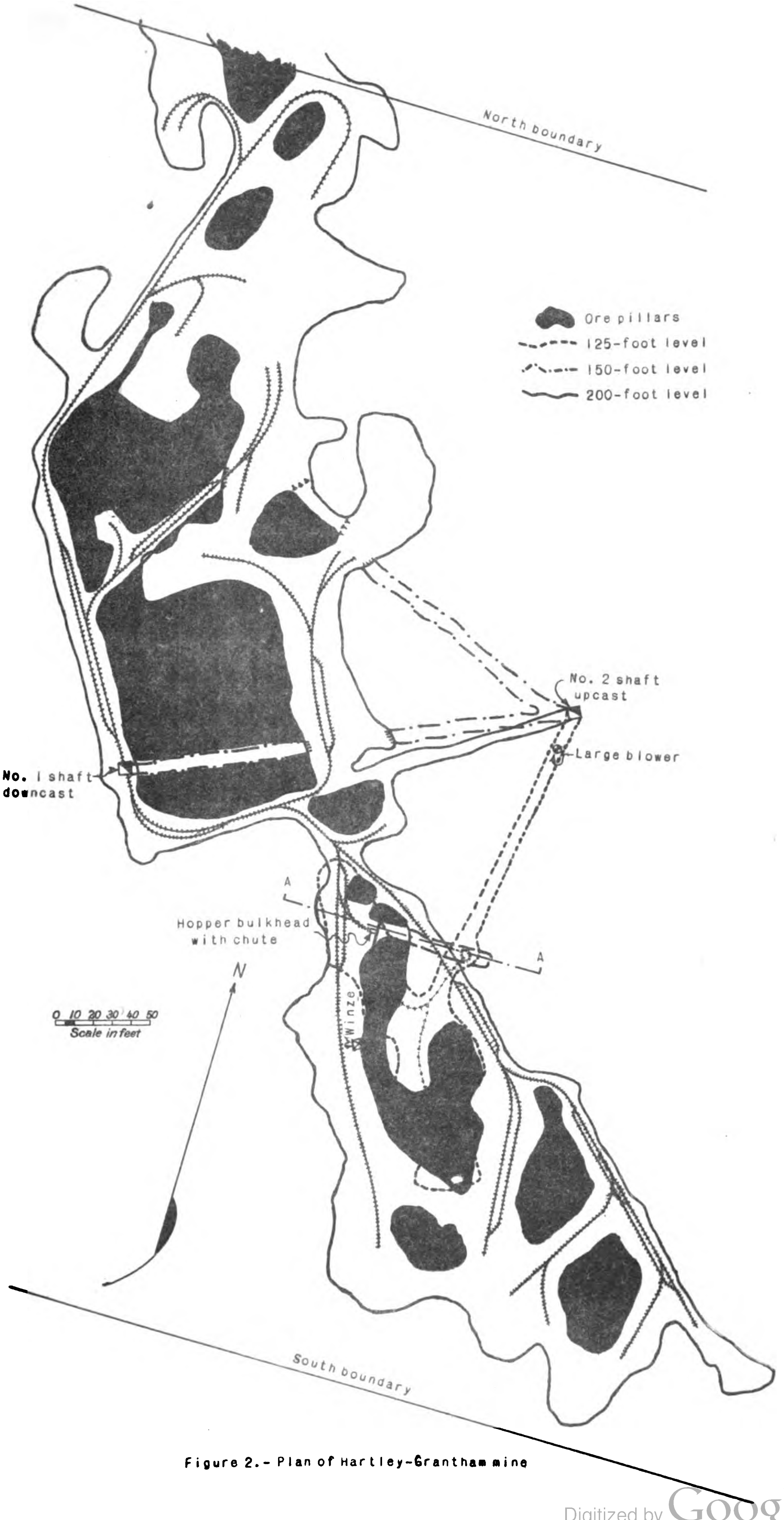


Figure 2.- Plan of Hartley-Grantham mine

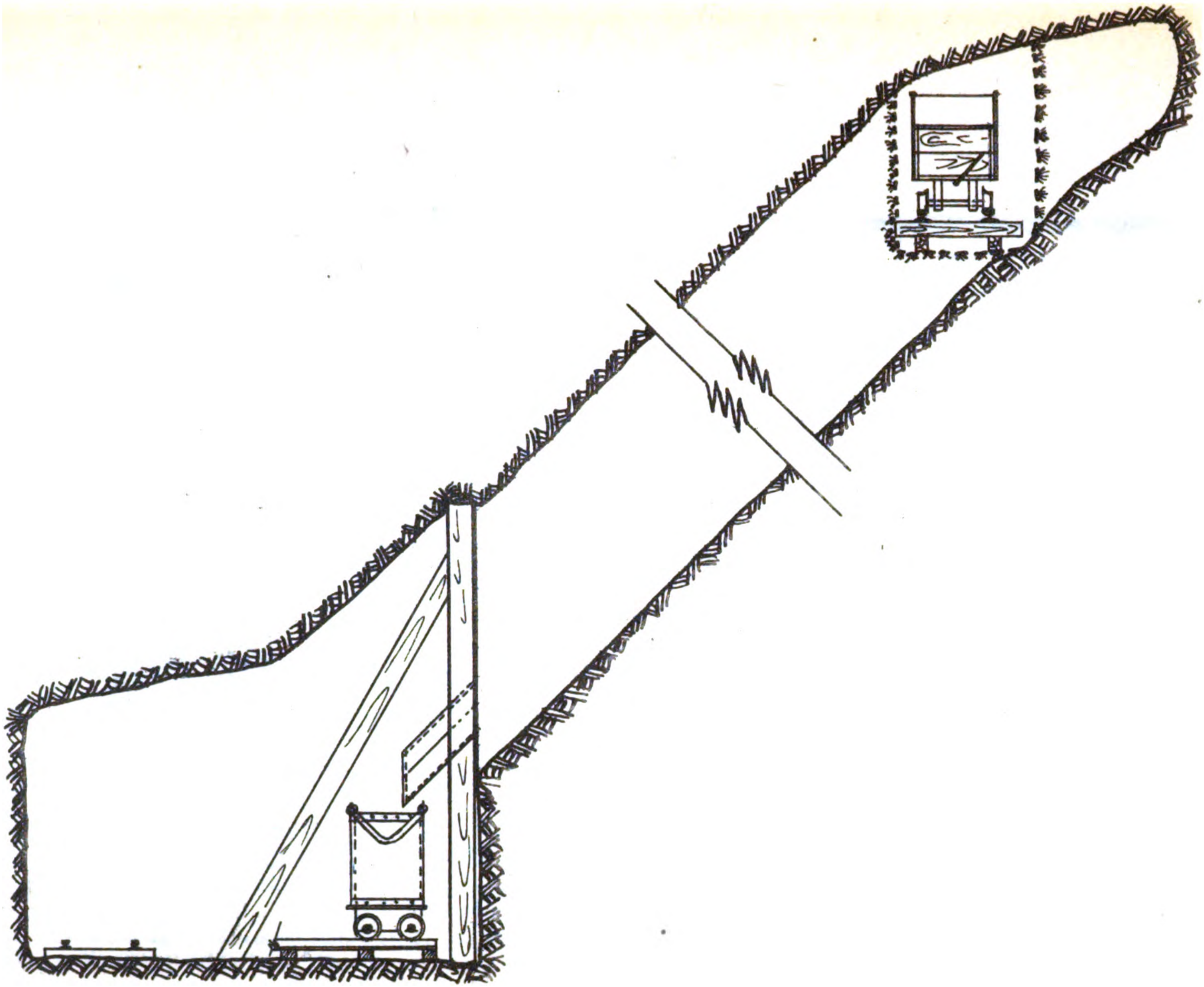
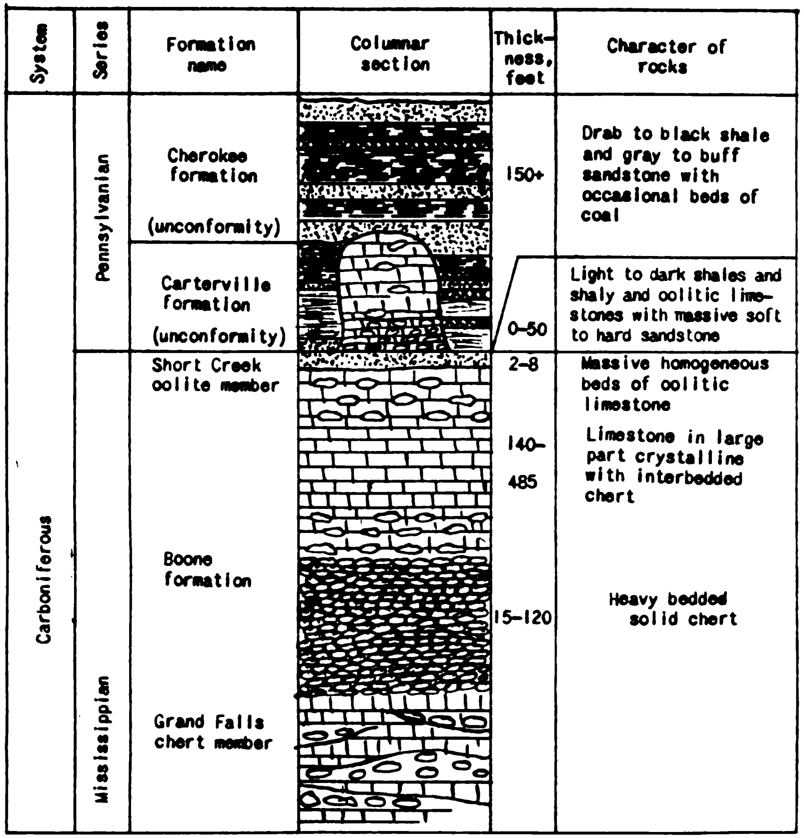


Figure 3.- Cross section A-A, Figure 2



System	Series	Formation name	Columnar section	Thickness, feet	Character of rocks
Carboniferous	Pennsylvanian	Cherokee formation (unconformity)		150+	Drab to black shale and gray to buff sandstone with occasional beds of coal
		Carterville formation (unconformity)		0-50	Light to dark shales and shaly and oolitic limestones with massive soft to hard sandstone
	Mississippian	Short Creek oolite member		2-8	Massive homogeneous beds of oolitic limestone
		Boone formation		140-485	Limestone in large part crystalline with interbedded chert
				15-120	Heavy bedded solid chert
		Grand Falls chert member			

Figure 4.- Generalized section of the Tri-State district, U.S.G.S. Joplin district folio reprint, No. 148

Not drawn to scale

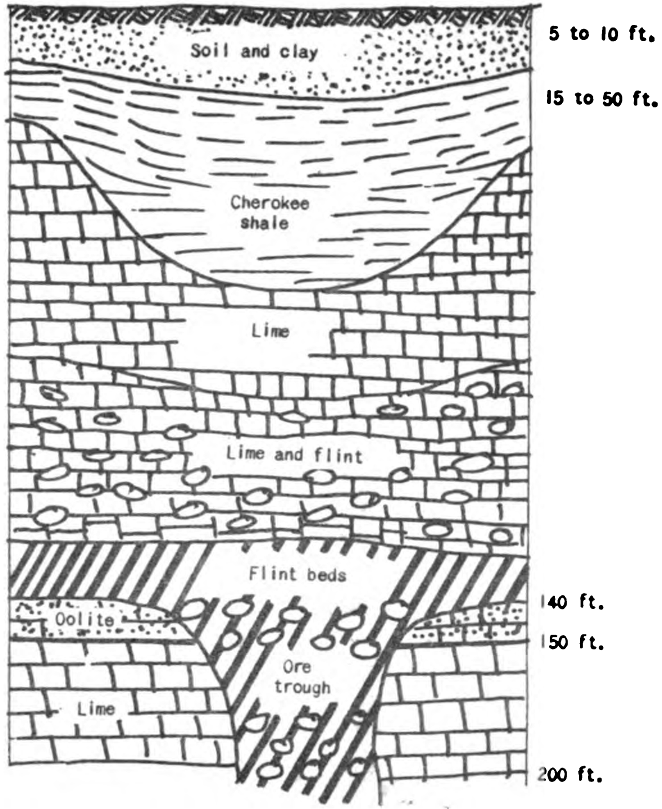


Figure 5.- Section across ore body taken at right angles to strike

The mining method of open stopes with pillar support is being used, but the character of the ground necessitates narrower stopes and larger pillars than are used in many other mines of the district.

The two shafts were sunk at the same time just outside the ore body where the drilling indicated firm ground. They were then connected by two pull drifts, one on the 200-foot level and one on the 150-foot level. Each shaft is 6 by 6 feet in cross section. No. 1 shaft is cribbed to the bottom and No. 2 shaft is cribbed for 15 feet from the surface only. No. 1 shaft became the mill shaft and is used for ore hoisting only, whereas all men and materials are handled at No. 2 shaft. Power, air, and water lines are carried down this shaft. The shafts were sunk on contract. The price paid the contractor was $7 per foot in shale and $10.50 per foot in rock. The contractor furnished labor and powder, and the company furnished all equipment such as machines, air, and steel and built the sinking derricks. The total cost to the company was about $18 per foot.

A standard shaft round, using fourteen 5-foot holes to the round was used in sinking the shafts. All holes were drilled with jackhammers. The four cut holes were drilled 5½ feet deep. An average of one box (50 lbs.) of 30 per cent gelatin powder was used in blasting and the rounds averaged 4½ feet in depth. Two drillers and two muckers were employed in drilling in each shaft. First the four cut holes were drilled, loaded, and blasted. The smoke was blown away and the muckers then mucked out. The remaining holes were then drilled and blasted, smoke blown out, and the shaft mucked clean. This cycle of operations consumed one shift. At the beginning of the shift in the morning the drill crew always had a cleaned shaft in which to start drilling.

Figure 6 shows the round drilled for pull drifts. Cut holes are drilled about 8 feet deep and all the others about 7 feet deep. The usual round consisted of 4 cut holes, 2 relief holes, 3 roof holes, 3 stope holes (lifters), and 2 side holes, 14 holes in all. The holes are drilled with a medium-weight Leyner-type drifting machine mounted on a 7-foot post or column and using 1-inch hollow hexagonal, lug shank steel. The steel is made up in 2-foot changes with 14° single-taper cross bits. The starters are made up with 2¾-inch gage and the changes with 3/16-inch difference in gage.

Two men are employed on the drill, usually at night, and the drift is mucked by one man on the opposite shift. One box of 40 per cent gelatin detonated by No. 8 caps constitutes the explosive charge. The costs of driving pull drifts are comparable to shaft sinking, but costs of cribbing and derricks are eliminated.

PRESENT MINING METHOD

The ore is mined by driving a heading next the roof and about 7 feet in height. The heading is usually carried three rounds or about 15 feet beyond the stope which follows behind the heading. In low ore the stope is carried through the full thickness of the ore. In high ore the stope is drilled and blasted with long flat stope holes at the bottom of the level, as shown in Figure 7, with intermediate rows of "splitter" holes as required, depending upon the height of the stope. Stope and splitter holes are drilled to a maximum of 18 feet in depth.

The rows of holes are from 7 to 10 feet apart vertically with two or three holes about 10 feet apart in each row, the number depending on the width of the stope. The stope holes (bottom row of holes) are drilled and blasted first, leaving a vertical face from 7 to 10 feet high. The broken ore is only partly loaded out, enough being left against the face upon which to set up a tripod for drilling the splitter holes. Where more than one row of splitter holes is required, the lower row is drilled and blasted first, and is followed in order by the higher rows.

Figure 7 shows the methods used for driving headings and drilling and blasting the stope or bench. Headings are drilled from a post and other holes from a tripod. The holes are loaded with 30 per cent gelatin powder and blasted with fuse and No. 8 caps. They are loaded to about two-thirds of the distance from the bottom and no stemming is employed.

Air is furnished by a single stage, gas driven compressor of 400 cubic foot capacity and a two-stage, belt-driven, electrically operated compressor of 800 cubic foot capacity, with working pressures each of 80 pounds. The gas compressor is used in the morning and evening, but during peak loads in the middle of the day it is shut down and the electric-driven compressor is started up. The air is carried to the drills through a 3-inch line with very little loss of head.

The steel is sharpened at another mine of the company and hauled to the Hartley-Grantham mine. One-half of the blacksmiths' wage is paid by each mine.

The average tonnage broken for the period reported upon was 76.68 tons per machine shift.

The character of the supporting ore and wall rocks is such that narrow drifts 18 to 25 feet wide and unusually large pillars are necessary. For the average stope three holes in a row are required to split the stope properly.

In the extreme southeast drift the heading is low and the stope is carried to the full height of the face.

After mining operations had started, two more pull drifts were driven - one northwest and one south of No. 2 shaft; the latter was driven to the minor horizon at the 125-foot level and the former was driven to the top of the ore body. This drift was later abandoned, as the stoping was carried from the lower level. A raise was driven from the lower level connecting the pull drift at the 125-foot level, and a hopper (fig. 8) was built merely by bulkheading this raise and installing a chute. Ore from the upper level is dumped into this hopper and drawn off into the hoisting cans on the lower or main haulage level.

All mucking is done by hand, and the ore is shoveled directly into hoisting cans which are set on small, four-wheel, roller-bearing trucks. In the upper level the ore is shoveled into a car which is dumped by a cradle arrangement into the hopper. The mucker, who is paid by the number of cans drawn off from the hopper, trams his own cans to the lay-by or storage track and takes an empty to his "lay out". From the lay-by, hand-trammers take the cans to the bottom. All

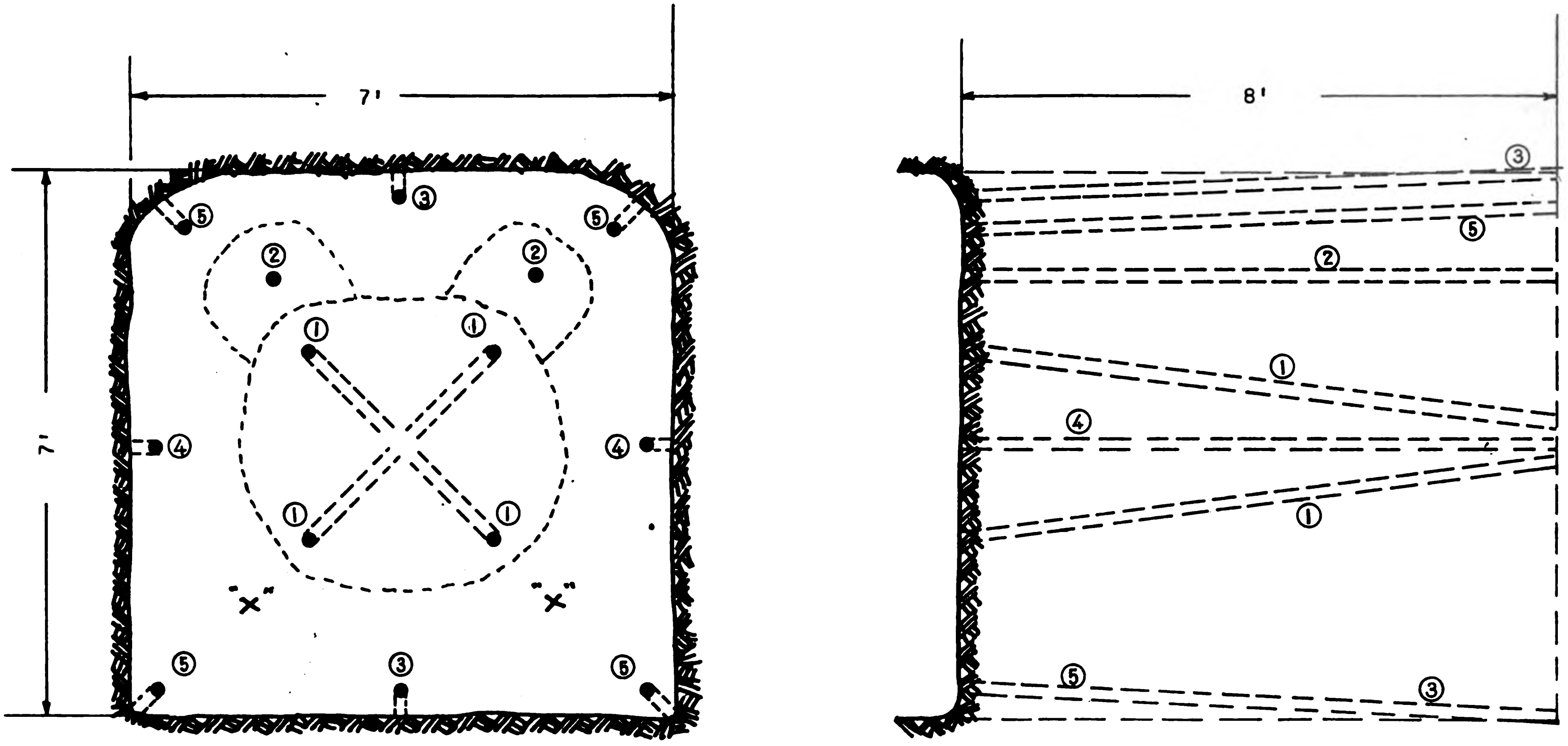


Figure 6.- Plan and profile of pull-drift round; circled numbers denote order of firing. Shaft round the same with addition of two extra relief holes at points marked "x"

wages for mucking are based on price per can, ranging from 11 to 13½ cents, depending upon the lay out, distance to lay-by, etc. Oak planks 2 inches thick are laid at the base of the stope, forming a platform upon which the ore is blasted or rolled down by the shoveler. Sometimes a "bruno" man is furnished by the company to assist the shoveler in keeping the ore rolled down upon this platform. Often he helps the shoveler, the two combining the bruno's wage and contract wage for shoveling, then dividing their wages equally. The average performance of the muckers during the first six months of 1929 was 29.36 tons per mucker shift.

There is but one hopper (fig. 8) in the mine, which consists of a bulkhead in the raise connecting the upper level; 6 by 8 inch timbers, spaced about 3 feet apart, are wedged between floor and roof. To the inner side are nailed 3-inch oak planks, and an opening 30 inches square is left for the chute. A movable slide operated by a hand lever forms the primary stop next to the bulkhead, and a hinged apron at the discharge end of the chute serves the double purpose of forming a secondary stop and lessening the space between the rim of the can and the end of the chute. This apron is also actuated by a long hand lever.

The cans are trammed to the bottom of the shaft to the hookers lay-by. The hooking crew consists of two bumpers and one hooker. One bumper is stationed at each side of the shaft. The truck with its full can is pushed by the bumper beneath the shaft on a single track where notches cut in the rails spot the can in the exact center. As the empty can returns from the derrick, the hooker pulls it off center to his platform, unsnaps the hook (which is provided with a spring tongue) raises the bail of the loaded can and snaps on the hook. The hoistman picks up the loaded can and hoists it to his dump. The hooker then rolls the empty can to the truck from which the loaded can was just taken, and the bumper pulls it away and spots another load. The operation calls for a good deal of team work between hoistman and hooker, as no signals are used except when the storage or hooking lay-bys are empty.

The hoist is an electrically driven geared hoist with a 75-hp., 220-volt motor and a maximum rope speed of 1,200 feet per minute. The average time for a round trip from bottom to dump to bottom is 29 seconds.

The track gage is 24 inches, and 12-pound rails are used throughout the mine.

PERCENTAGE OF EXTRACTION

At present approximately 40 per cent of the area of the developed ore body is left for pillars. Drilling and development operations prove that these pillars are as well mineralized as the area that has been mined out. As previously mentioned, the character of the ground necessitates leaving these pillars for adequate support. No precise factor can be determined relative to the dilution of ore by waste except as actual mill recovery shows the ratio of gangue to concentrates. No bowlders are discarded either underground or on top. The entire tonnage hoisted is milled. When the mine enters the clean-up period the pillars will be pulled or robbed with a maximum extraction of the total ore body closely approaching 100 per cent.

WAGE, CONTRACT, AND BONUS SYSTEM

Labor is based on an eight-hour day. Muckers are paid from 11 to 13½ cents per can according to the lay out and length of haul to the lay-by or gathering track. This wage fluctuates with the ore market, but is based on a price of $40 per ton of concentrates. For every $5 increase, shift wages are automatically increased 25 cents per day and muckers 1 cent per can. On a downward market all wages are correspondingly decreased. This however, is the general practice throughout the district. The average wage scale at this mine based on $40 per ton concentrates is as follows:

Ground foreman	$55.00	per week
Hoisterman	35.00	Do.
Blacksmith	42.00	Do.
Bumpers	3.75	per shift
Machine operators	4.25	Do.
Machine helpers	3.75	Do.
Roof trimmers	4.75	Do.
Trammers	3.75	Do.
Trackmen	4.50	Do.
Shift shovelers	3.75	Do.
Hopper puller	3.75	Do.

VENTILATION

The ventilation of the lower level is natural. No. 1 shaft and the shaft on the adjoining lease to the north (which grounds are cut together) are downcast and No. 2 shaft is upcast. A large force draft blower is installed at No. 1 shaft to assist the circulation and to prevent the draft from changing.

In the upper level the ground is extremely hot and the ventilation and cooling of this ground presents a difficult problem. A large blower is installed behind a brattice in the pull drift on the 125-foot level close to No. 2 shaft. This forces the air up at No. 2 shaft, pulling some fresh air through the hopper raise and through a glory hole between the upper and lower level. Blowers on the surface were installed over all churn-drill holes and an additional hole was drilled at the south and exclusively for air. This hole is 8 inches in diameter instead of the usual 6¼ inches, and increased efficiency due to the larger diameter with lower friction losses more than double the amount of free air displaced.

FIRE HAZARDS

As there is no timbering in the workings, nor explosive gases, the fire hazard is negligible. There are one or more means of egress through different shafts or other properties, so that the men are in little or no danger in case of fire at any of the surface plants.

SAFETY METHODS

The company maintains a full-time safety engineer who makes regular and systematic examinations of all workings and equipment and is empowered to enforce any safety measures he may deem necessary. Weekly safety meetings are held under the guidance of trained safety workers. At each meeting a definite subject is brought up for discussion, in which all the men take part. Safety posters are displayed on the bulletin board in the change house and at other conspicuous points.

High stopes and faces are illuminated by electric flood lamps.

Table 1. - Summary of Costs

Hartley-Grantham mine Period covered: January to June, 1929

Tons ore hoisted during period: 60,281.9

Mining method: Open stopes with pillar support.

Underground Costs Per Ton of Ore Hoisted

	Labor	Supervision	Compressed[1] air drills and steel	Power	Explosives	Other supplies	Total
Development[2]	- -	- -	- -	- -	- -	- -	- -
Mining	$.3433	- -	$.0522	$.0061	$.1067	$.0078	$.5161
Transportation[3]..	.1196	.0371	- -	.0304	- -	.0092	.1963
General underground expense.	.0151	- -	- -	- -	- -	.0339	.0490
Surface expense (applicable to underground)..	.0203	- -	- -	- -	- -	- -	.0203
Total	.4983	.0371	.0522	.0365	.1067	.0509	.7817

1 Includes gas for compressing air.
2 No development in rock during period.
3 Includes hoisting.

TABLE 2. - SUMMARY OF COSTS IN UNITS OF LABOR, POWER, AND SUPPLIES

Hartley-Grantham mine Period covered: January to June, 1929

Tons ore hoisted during period: 60,281.9

Mining method: Open stopes with pillar support

A. Labor (man hours per ton):

Breaking (drilling, blasting, and trimming)	.218
Mucking	.272
Haulage and hoisting	.220
Supervision	.024
General	.011
Total labor underground	.745
Average tons per man-shift underground	10.74
Average tons per man-shift surface labor .... (properly chargeable to underground)	312.00
Labor, percentage of total cost	63.7

B. Power and supplies per ton:

Explosives (lbs. per ton) 30 per cent gelatin		.741
Power:		
Air compression (gas)	31.78 cu. ft.	
Hoisting	1.85 kw.h.	
Ventilation and lighting	.04 kw.h.	
Total kilowatt-hrs per ton underground		1.89

Other supplies in percentage of total power and supplies..	36.4
Power, materials, and supplies, percentage of total underground cost	36.2

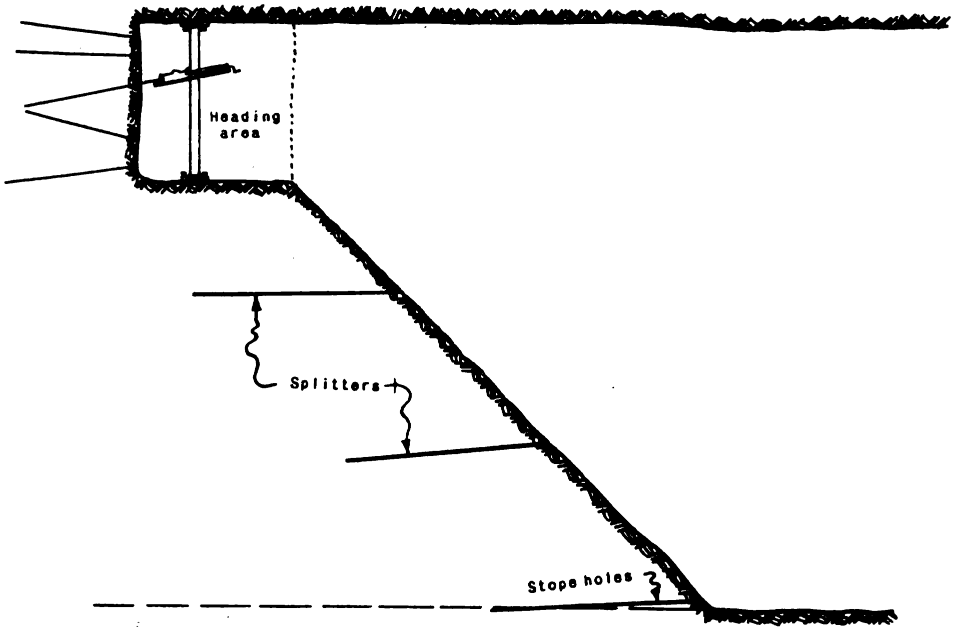


Figure 7.- Method of advancing stopes to headings by "splitter holes"

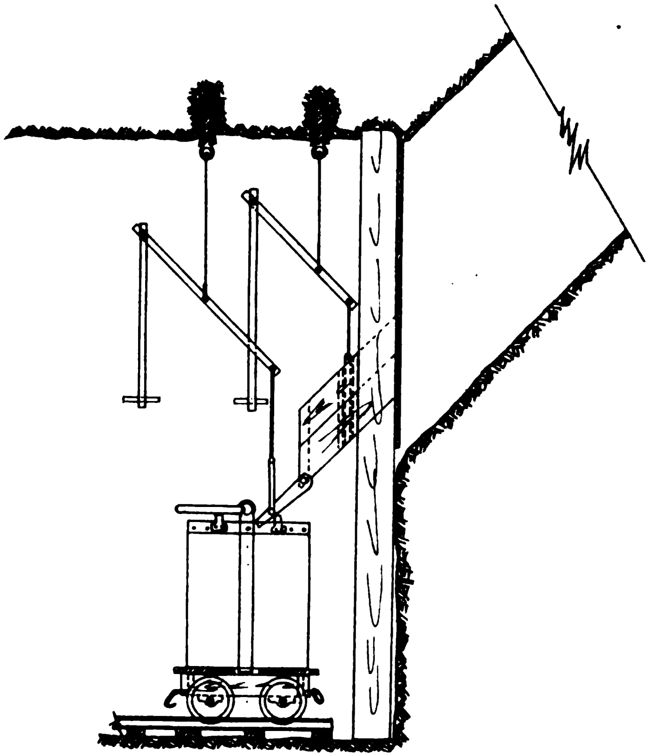


Figure 8.- Hopper